COMBUSTION METHOD, COMBUSTION DEVICE AND COMBUSTION SYSTEM FOR BURNING WATER-FUEL EMULSION USING ELECTROMAGNETIC WAVE HEATING

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to any methods, devices and systems for burning fossil fuels and/or utilizing the generated heat energies, particularly, a combustion method, a combustion device and a combustion system which burns a high water/oil ratio water-fuel emulsion using electromagnetic wave heating with reduced fuel consumption and carbon oxide emission (CO, CO_2), thus contributing to environmental protection.

DESCRIPTION OF RELATED ART

In an industry where a large amount of heat energy is consumed or in an industry for manufacturing a variety of devices/equipment for converting/utilizing heat energy, particularly in a diesel engine related field and in a field related to industrial/domestic use boilers/burners where a reduction in carbon dioxide emission has long been demanded, research and development has been carried out regarding combustion of water-in-oil emulsion of water and fossil fuel, such as heavy oil, light oil and kerosene or the like, and it has been a common concern to find how to increase the ratio of the water to fuel.

Water-in-oil emulsion is an unstable fuel composed of oil and water with no affinity with respect to one another. They are forcibly admixed, and the emulsion is not a stably supplied product. Accordingly, in cases where water-in-oil emulsion is used, it is usual practice on application to make investigations

into the technology related to the manufacture of water-in-oil emulsion. This emulsion should not separate into compositions within a short period of time after the manufacturing step, and should maintain a high degree of dispersion of oil and water. Even in cases where combustion device has adequately performed, the presence of insufficient conditions for water-in-oil emulsion results in an inability to obtain a favorable combusting condition. In order to achieve combustion of water-in-oil emulsion, the combustion device is required to perform not only as a combustion device but also as an emulsifying equipment.

For emulsifying equipment, it has been usual practice to utilize a system in which water, oil and emulsifying agent quantitatively weighed or metered at a given ratio are introduced into a mixing tank which has mixing blades provided therein and a drive motor to rotate the mixing blades for mixing the oil, water and emulsifying agent. However, water-in-oil emulsion produced by such a mixing system contains dispersed oil and water of large particle sizes, respectively maintaining properties of oil and water. The both particles can easily separate from one another and even when combusted immediately after the formation of water-in-oil emulsion, oil particles combust and water particles vaporizes with no interaction therebetween. That is, the water mixed in the oil has no contribution to generation of heat and, on the contrary, an ignitability of oil is deteriorated. As a counter measure, attempt has been made to adopt a multiple-stage mixing processes in which water-in-oil emulsion obtained from a first mixing tank is sent to and treated by second and third mixing tanks which have mixing blades formed in different shapes, respectively. Thus, the emulsifying system is inherently of a large-scale that requires a considerably large

installation space regardless of for domestic use or for industrial use, and it is desired to provide a small-size and high performance emulsifying system.

Combustion device is also required to take reasonable measure for burning an emulsion fuel of high water/oil ratio. A water-in-oil emulsion fuel is naturally hard to burn rather than fuel with no water mixed, no matter how ideal the emulsion will be. Approach has been made to counter this problem, in which an ignitability of fuel is maintained by atomizing water-in-oil emulsion into a high temperature vaporizing chamber and burning a mixture of steam and heated oil gas produced by the chamber. Since a remarkable difference exists in volumetric ratio between liquid and gas, combustion device is required to have an extremely large-size vaporizing chamber equipped with a fuel consuming large-size pilot burner. The large-size vaporizing chamber consumes a large amount of normal fuel for maintaining high temperature, compensating heat of vaporization of the water-in-oil emulsion.

With the combustion system of the related art composed of emulsifying equipment and combustion device, as set forth above, the emulsifying equipment must be a large-scale system and, in addition, the vaporizing chamber of combustion device cannot be miniaturized. Therefore, it is hard to avoid various issues such as excessive increases in manufacturing cost, running cost, installation cost of the system and installation space in terms of a heat value resulting from the burner, and a status quo resides in that the system does not yet result in spread applications.

The related art combustion system has further involved in an essential issue where a difficulty is encountered in

increasing a substantial water/oil ratio when observing the system as a whole for the following reason: That is, if combustion device is enabled to be configured to combust water-in-oil emulsion at the water/oil ratio of 1 : 1, the water/oil ratio of the whole system falls in the water/oil ratio of 2 : 1.

Moreover, even though combustion of water has been observed as a phenomenon, no theory has been established for a mechanism resulting in such phenomenon. In this respect, there is an influential theory in that steam explosion occurs in water as a result of combustion of oil in water-in-oil emulsion to cause extremely critical oxidizing reaction to occur for permitting water to be separated into hydrogen and oxygen and opinion of Agency of Industrial Science and Technology suggests that extremely critical oxidizing reaction is possible to occur at a temperature of 500℃ under a condition greater than 300 atm. Also, while in the related art, the water/oil ratio of water-in-oil emulsion to be available for combustion in the burner is selected to lie at a ratio of fuel and water of 1 : 0.3, the latest investigation made on the private sector demonstrates enterprise judgment in that water-in-oil emulsion is possible to combust even at the water/oil ratio of 3 : 1. However, in view of the opinion of Agency of Industrial Science and Technology set forth above, it is difficult to consider that the burner device with an open structure is able to establish the condition above 300 atm. Accordingly, this seems to be based on understanding that visual igniting phenomenon of water-in-oil emulsion is wrongly regarded as burning of water.

SUMMARY OF THE INVENTION

The present invention was made in the light of this problem.

An object of the present invention is to provide an electromagnetic wave heating type combustion system which includes a compact emulsifying equipment and a combustion device with a compact vaporizing/heating chamber in a range for practical use, and to provide a method for burning water-in-oil emulsion at a high water/oil ratio, lowering a critical condition under which extremely critical oxidizing reaction occurs.

An aspect of the present invention is a method for burning emulsion fuel, comprising: atomizing emulsion fuel; and heating the atomized fuel by electromagnetic wave heating.

Another aspect of the present invention is a system for burning emulsion fuel, comprising: a device for burning emulsion fuel comprising an atomizer for atomizing emulsion fuel and a chamber in which the atomized fuel is subjected to electromagnetic wave heating; and a fuel supply system for supplying the emulsion fuel to the atomizer, which includes a mixer for mixing water and fuel, comprising a pair of first and second plates parallel to each other, each of the plates provided on its opposite face with a plurality of holes arranged in a honeycomb pattern.

The electromagnetic wave heating type combustion system has features related to technology of emulsifying fuel and water, and to combustion of water-in-oil emulsion.

The feature related to emulsifying technology resides in the use of a static mixer with no movable parts such as those used in the mixing device that incorporates the mixing blades of the related art. The static mixer is configured in a simple structure composed of only a honeycomb labyrinth unit that is disposed in a passage that admits the flow of rough blend mixture between water and fuel that are quantitatively weighed or metered

and makes it possible to produce nearly the most ideal water-in-oil emulsion, that can be obtained in the present days, within a short period of time, while enabling to achieve remarkable miniaturization in scale of a device. Also, the static mixer for use in the combustion system of the present invention has been already independently issued as a patent for a static mixer.

The honeycomb labyrinth unit for use in the static mixer is comprised of a diverging section and a converging section. The diverging section serves to compel water and fuel, simultaneously forced into one portion, to be split through labyrinth passageways into multiple flow streams. The labyrinth passageways are formed in a mesh-like configuration rather than a tree-like configuration to provide a mechanism by which the flow of mixture is split in the multiple streams while repeatedly causing flow splitting and confluence in part. Also, the converging section has a function to permit the flows of water and fuel, split in the multiple streams, to pass through labyrinth passageways and joined at one portion. Thus, the diverging section and the confluence honeycomb are used in a pair to form a honeycomb labyrinth unit in one unit.

In addition, a particularly advantageous point of the static mixer resides in a capability of increasing a dispersion rate of oil and water in proportion to the number of units depending upon the number of units of the honeycomb labyrinth units to be used. Accordingly, the number of units to be used of the honeycomb labyrinth units can be freely determined based on applications of water-in-oil emulsion and demanded water/oil ratios, provided that an increase in the number of units results in an increase in given force feed pressure under which roughly

blended oil and water fuel is press forced to the static mixer. Also, due to the absence of the movable component parts, the honeycomb filer unit is extremely small in structure and, so, it is possible to neglect a probability of enlargement in scale of the device due to an increase in the number of units.

Further, the feature related to combustion of water-in-oil emulsion of the present invention resides in that water-in-oil emulsion is combusted by lowering the temperature critical point and the pressure critical point at which extremely critical oxidizing reaction occurs in water molecule contained in water-in-oil emulsion. And, as a means to achieve such a purpose, a process is adopted in which a high frequency coil is wound on a combustion chamber to ignite water-in-oil emulsion under a state where water molecule of water-in-oil emulsion sprayed into the combustion chamber are heated with electromagnetic waves. It is widely known that high frequency electromagnetic waves are effective to achieve excitation heat of the water molecules and applied in an electronic oven, etc.

And, when water-in-oil emulsion is sprayed into a high frequency electromagnetic field, initially, steam explosion occurs in water contained in a fuel droplet in a micro-size unit prior to combustion of oil. This point is particularly important and fundamentally different from a combustion mechanism of water-in-oil emulsion in the related art device. That is, in the related art device and theory, oil combusts in advance of water to cause steam explosion to occur in water under resulting pressure and heat and, subsequently, combustion shifts to extremely critical oxidizing reaction of water. This point is mostly questionable because of the following reason: It is considered that due to a probability wherein at time when water

shifts to extremely critical oxidizing reaction, combustion of oil is terminated and heat energy resulting from combustion of oil is consumed for steam explosion of water, there is almost no energy left for inducing steam to be subjected to extremely critical oxidizing reaction.

In contrast, the present invention contemplates the use of energy resulting from high frequency electromagnetic waves for permitting steam explosion to occur in advance and then causing oil to combust. And, in the influence of energy resulting from combustion of oil, steam rapidly reaches to extremely critical state for combustion. That is, the water molecule changes in mode to hydrogen gas and oxygen gas by which combustion occurs. Here, due to a probability wherein no temperature and pressure in the combustion chamber exceed certain limitations in the open device, with one end being opened, such as the burner device, it is reasonable to consider that the temperature critical point and the pressure critical point at which extremely critical oxidizing reaction occurs in the water molecule are lowered, and this is based on a structure wherein water-in-oil emulsion is ignited under a condition where fuel is heated with the electromagnetic waves.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with reference to the accompanying drawings wherein:

FIG.1 is a diagram showing a configuration of a system according to a first embodiment of the present invention.

FIG.2 is a partially sectional view of a mixer in the system according to the first embodiment of the present invention.

FIG.3 is a perspective view showing a unit of honeycomb

labyrinth units stacked in the mixer in Fig. 2.

FIG.4 is an exploded perspective view showing the unit of honeycomb labyrinth units stacked in the mixer in Fig. 2.

FIG. 5 is a cross sectional view of a combustion chamber of a burner in the system according to the first embodiment of the present invention, for explaining mechanism of combustion of emulsion fuel therein.

FIG. 6 is another cross sectional view of the combustion chamber of the burner in Fig.5, showing mechanism of combustion of the emulsion fuel therein.

FIG. 7 is a diagram showing a configuration of a system according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the present invention will be explained below with reference to the drawings, wherein like members are designated by like reference characters.

As shown in FIG. 1, a combustion system S1 for burning water-in-oil emulsion using an electromagnetic wave heating includes an emulsifying unit constituted of a fixed quantity mixer system 10 and a static mixer 20 with no moving parts, and a burner 30 as a combustion device.

The mixer system 10 includes an agitator unit 14, and three tanks of a water tank 11, a fuel tank 12 and an emulsifying agent tank 13 connected to the agitator unit 14 through lines 11c, 12c and 13c, respectively. In the respective water tank 11, fuel tank 12 and emulsifying agent tank 13, level sensors 11a, 12a and 13a are provided to monitor levels of the respective water, fuel, emulsifying agent therein and to alert shortages thereof. On the lines 11c, 12c and 13c from the respective water tank

11, fuel tank 12, emulsifying agent tank 13 to the agitator unit 14, control valves V1, V2 and V3 and feedback systems 11b, 12b and 13b associated with the respective valves V1, V2 and V3 are provided to automatically control flow rates of the water, fuel and emulsifying agent to be supplied to the agitator unit 14. Thus, in the mixer system 10, the water, fuel and emulsifying agent are metered/weighed and mixed together at a preset water/fuel ratio to be fed to the static mixer 20.

The mixed water and fuel is pressurized and fed to the static mixer 20 by a feed pump 15. On a line 15a from the feed pump 15 to the static mixer 20, a pressure regulator valve V4 with a pressure gauge 10 is provided, by which feed pressure of the mixed water and fuel is adjustable to a desired level.

The static mixer 20 is constituted of a housing 21 and a plurality of honeycomb labyrinth units 22 stacked in multiple stages in the housing 21. The mixed water and fuel is forced into the housing 21 through an inlet 21a of the static mixer 20, to pass through between the honeycomb labyrinth units 22 where the water and fuel is repeatedly sheared to split and converged and emulsified into water-in-oil emulsion in which water is dispersed in a oil phase as droplets in the range of sub-microns in diameter, and discharged from an outlet 21b of the static mixer 20.

The produced water-in-oil emulsion is once stored in a depressurization tank 17 under atmospheric pressure, and then fed to the burner 30 by a fuel pump 18. On a line 18a from the fuel pump 18 to the burner 30, a throttle valve V5 is provided to regulate the feeding rate of the emulsion fuel to the burner 30.

The burner 30 is constituted of a pre-loading chamber 31,

a combustion chamber 32, around which a high frequency coil 34 of a water-cooled copper tube is wound, an atomizer nozzle 33 through which the water-in-oil emulsion pre-loaded at an appropriate level is sprayed into the combustion chamber 32 to produce a spray of droplets of the emulsion, and a high frequency AC power supply 35. The burner 30 serves as a combustion device which heats the spray of water-in-oil emulsion in the chamber 32 by electromagnetic wave heating and burns the heated spray thereof.

The description will be made to the detail of the respective components of the combustion system S1.

The housing 21 of the static mixer 20 is formed in a cylindrical shape, as shown in FIG. 2, having flanges 21f at both ends thereof. A pair of end plates 23 are provided to close the openings at both ends of the housing 21, each of which are fixed to the flanges 21f by bolts b1 penetrating therethrough. The inlet 21a through which the mixed water and fuel is introduced into the mixer 20 is formed on one of the end plates 23, and the outlet 21b through which the water-in-oil emulsion is discharged is formed on the other end plate 23. Inside the housing 21 next to the respective end plates 23, a pair of pressure blocks 24 are provided axially displaceable to approach each other. On both of the end plates 23, a plurality of pressure bolts b2 are provided therethrough with the tip thereof inside the housing 21 in contact with the pressure blocks 24, whereby, by screwing the pressure bolts b2 in, the pair of pressure blocks 24 set an appropriate pressure on the stacked honeycomb labyrinth units 22 sandwiched therebetween.

The honeycomb labyrinth unit 22 is constituted of a diverging section 22A and a converging section 22B arranged

parallel to each other as shown in FIG. 3. As shown in FIG. 4, the diverging section 22A is constituted of an outer honeycomb labyrinth disk 220A provided on its central part with an inlet 220E through which the mixed water and fuel is introduced into the unit 22, and an inner honeycomb labyrinth disk 220B with no opening such as the inlet 220E provided thereon. Similarly to the diverging section 22A, the converging section 22B is constituted of an outer honeycomb labyrinth disk 221A provided on its central part with an outlet 221D through which the oil-in-water emulsion is discharged out of the unit 22, and an inner honeycomb labyrinth disk 221B with no opening such as the outlet 221D. The outer and inner honeycomb labyrinth disks 220A and 220B are formed to have, on their surfaces opposite to each other, ribs 220K and 220L, respectively, each of which is continuous in a hexagonal mesh-like configuration, forming a plurality of hexagonal holes 220H thereon arranged in a honeycomb pattern. The outer and inner honeycomb labyrinth disks 220A and 220B are mated in a manner that the respective ribs 220K, 220L are positioned not to be in alignment with each other and the respective hexagonal holes 220H on the disks 220A and 220B off to the side of one another. Specifically, the disks 220A and 220B are mated in a manner that each of the hexagonal holes 220H on one of the disks 220A and 220B is arranged so that a meeting point of the rib 220K or 220L between three of the holes 220H is located at a center point of the opposing hexagonal hole 220H on the other disk. In addition, the inner honeycomb labyrinth disk 220B is formed to have three positioning projections 220F on its rim part with equally provided spaces in a circumferential direction, which ensure the positions of the hexagonal holes 220H when the disks 220A and 220B are mated. Similarly to the

disks 220A and 220B, the outer and inner honeycomb labyrinth disks 221A and 221B of the converging section 22B are formed to have, on their surfaces opposite to each other, ribs 221K and 221L, respectively, each of which is continuous in a hexagonal mesh-like configuration, forming a plurality of hexagonal holes 220H thereon arranged in a honeycomb pattern. The outer and inner honeycomb labyrinth disks 221A and 221B are mated in a manner that the respective ribs 221K, 221L are positioned not to be in alignment with each other and the respective hexagonal holes 220H on the disks 221A and 221B off to the side of one another. In addition, the inner honeycomb labyrinth disk 221B is formed to have three positioning projections 221F on its rim part with equally provided spaces in a circumferential direction, which ensure the positions of the hexagonal holes 220H when the disks 221A and 221B are mated. Thus, the mated honeycomb labyrinth disks 220A and 220B cooperate to define a diverging flow path therebetween for the water and fuel or water-in-oil emulsion introduced through the inlet 220E. The mated honeycomb labyrinth disks 221A and 221B cooperate to define a converging flow path therebetween for the emulsion to be discharged through the outlet 221D.

The water and fuel or water-in-oil emulsion introduced through the inlet 220E of the honeycomb labyrinth unit 22 flows through the diverging flow path in the diverging section 22A, out from a gap between the disks 220A and 220B on outer periphery of the diverging section 22A, and then flows into a gap between the disks 221A and 221B on outer periphery of the converging section 22B, through the converging flow path in the converging section 22B, out of the outlet 221D. In the diverging or converging flow path, the water and fuel or the emulsion are

forced to be repeatedly sheared and split, flowing from one of the holes 220H on one disk to a couple of opposing holes 220H on the other disk. In the honeycomb labyrinth units 22 stacked in multiple stages, the water and fuel repeatedly flows through such paths, whereby the static mixer 20 can produce the water-in-oil emulsion with an enhanced degree of dispersion in proportion to the number of the honeycomb labyrinth units 22 therein.

As shown in FIG. 1, the water-in-oil emulsion from the static mixer 20 is sent to the pre-loading chamber 31 of the burner 30 and is atomized through the atomizer nozzle 33 into the combustion chamber 32 to be heated. In the first embodiment, the spray of the emulsion is heated principally by radiation from or partially by convective heat transfer through contact with the body of the heating chamber 32 that is heated by an induction heating with the high frequency coil 34. The heating chamber 32 may be made of a material such as a conductive material having a high melting point with appropriate electrical resistance. As shown in FIG. 5, the atomized water-in-oil emulsion in the combustion chamber 32 is a spray of water droplets X1, oil droplets Y1, and droplets Z1 of oil containing water dispersed in the oil phase. When the spray is heated, due to the lower boiling point of water than that of the oil, explosive vaporizations or micro-explosions first occur on the water droplets X1 or the internal water droplets in the droplets Z1. The vaporizations of the water droplets X1 cause rapid expansion of the oil droplets Y1 or the surrounding oil of the droplets Z1, fragmenting the oil into smaller droplets. As a result, as shown in FIG. 6, uniform oil and water mixture gas XY of fine particles is formed, whereby the water molecule can transit to

its critical state upon igniting. That is, an atmosphere of the induction-heating inside the combustion chamber 32 lowers a temperature critical point and a pressure critical point at which an extremely critical oxidizing reaction occurs in water molecule.

With a second embodiment of the present invention shown in FIG. 6, the water-in-oil emulsion is delivered through the pre-loading chamber 31 of the burner 30, atomized through the atomizer nozzle 33 into a combustion chamber 40, and then radiated in the combustion chamber 40 with microwaves guided through a wave-guide tube 41 from a microwave generator 42 (such as a magnetron) to be subjected to electromagnetic excitation heating (microwave heating). Other members, components and parts, functions and operations thereof in the second embodiment are similar to those of the first embodiment, with like members designated by the same reference numerals.

In the foregoing description, an emulsifying agent is not necessarily required for an application in which a water-in-oil emulsion is used within a short period of time after being discharged from the static mixer 20. This is because the static mixer 20 is capable of producing a stable emulsion with a high degree of dispersion, oil and water of which is inseparable within the short period of time. Also, the frequency and voltage of the high frequency alternating current to be applied to the high frequency coil 34 may be adjusted depending upon a water/oil ratio of the emulsion, size or material of the combustion chamber 32.

As set forth above, the electromagnetic wave heating type combustion system of the present invention is possible to effectively combust water-in-oil emulsion, by the provision of

an atmosphere of electromagnetic wave heating generated by the high frequency coil, while lowering the temperature critical point and the pressure critical point at which extremely critical oxidizing reaction occurs in water molecule. The static mixer can emulsify water and fuel into water-in-oil emulsion at a high degree of dispersion, enabling water-in-oil emulsion with a high water/oil ratio to be stably combusted, eliminating the need of providing a large-sized vaporizing/heating chamber, which is preheated at a high temperature using normal fuel, for a small-sized practical burner.

The preferred embodiments described herein are illustrative and not restrictive, and the invention may be practiced or embodied in other ways without departing from the spirit or essential character thereof. The scope of the invention being indicated by the claims, and all variations which come within the meaning of claims are intended to be embraced herein.

The present disclosure relates to subject matter contained in Japanese Patent Application No. 2003-023712, filed on January 31, 2003, the disclosure of which is expressly incorporated herein by reference in its entirety.